Accelerating Energy-Efficiency Improvements in Room Air Conditioners in India: Potential, Costs-Benefits, and Policies

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Summary

- Room Air Conditioners (ACs) uptake in India is increasing; may add 140 GW (30%) to peak load by 2030
- Between 2006 & 2016, market average room AC efficiency improved by ~35% (3% per year) while inflation-adjusted room AC prices declined by ~35%
- In this study, we assess the technical feasibility, cost-benefit, and required policy enhancements for further accelerating the efficiency improvement of room ACs in India
- The most efficient room AC on the Indian market is almost twice as efficient as the market average
  - Technology may not be a constraint in accelerating the room AC efficiency
  - Japan and Korea have doubled AC efficiency in 7-10 yrs while inflation-adjusted AC prices declined
- If starting 2018, market average room AC efficiency improves at 6%/yr instead of historical rate of 3%/yr:
  - ~40GW of peak load could be avoided by 2030 (equivalent to ~80 power plants of 500MW each), and
  - ~64TWh/yr of energy could be saved by 2030 (equivalent to current electricity consumption of Gujarat state)
- Consumer benefits of enhancing AC efficiency far outweigh the incremental cost
  - The net present value (NPV) of the consumer benefit between 2018 and 2030 will range from:
    - Rs 4,000 Cr or $600 million (if AC prices increase based on the current cost of efficiency improvement) to
    - Rs 173,000 Cr or $25 billion (if AC prices not affected by efficiency improvement, per historical experience)
  - Rebound effect may reduce the financial benefit but it would not affect the overall consumer welfare
- This benefit is achievable by ratcheting up the room AC MEPS to the level of current (2016) five-star rating for inverter ACs by 2022 and to current (2016) best available technology in the market by 2026
- Bulk procurement (similar to the UJALA LED Program) and incentive programs would be crucial for such market transformation especially for pulling up the top of the market

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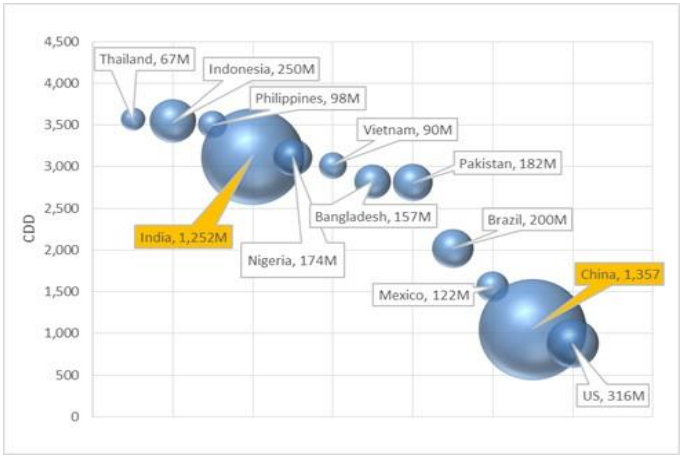
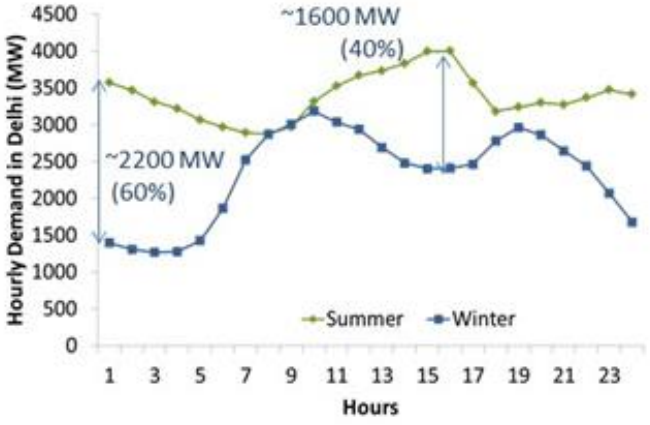
The Need to Meet Space Cooling Demand Sustainably



CDD: Cooling Degree Days
Size of the bubble indicates population
(Source: Davis and Gertler, 2015)

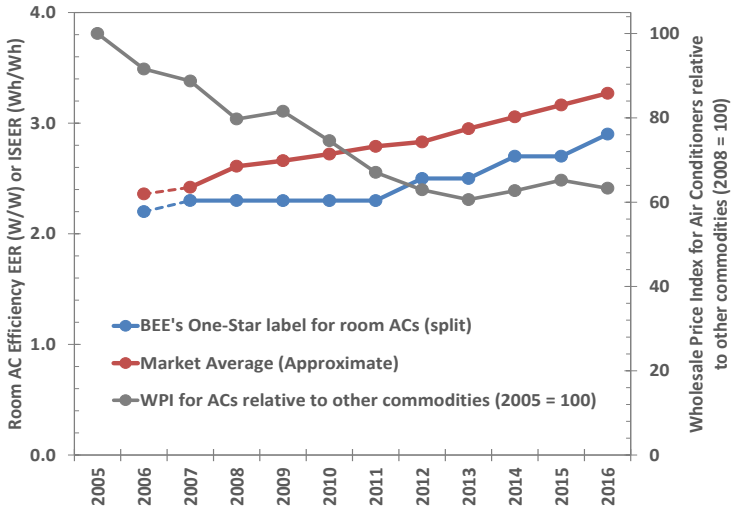
- Given rising incomes, increasing urbanization, and high cooling requirements, Air Conditioner (AC) use is increasing rapidly in India
  - India has one of the highest air conditioning potential in the world (top chart)
  - In India, only ~5% urban households owned a room AC in 2011 but sales are increasing at 12-15% per yr
  - In China, AC penetration in cities grew from ~5% in 1995 to over 100% in 2008



- By 2030, room ACs could add about 140 GW (~35%) to the peak load in India (equivalent to ~300 power plant units of 500 MW each)
- In areas with significant AC penetration, utilities are already facing significant peak load impacts
  - For example, in Delhi, space cooling represented ~40-60% of the summer peak load in 2014 (bottom chart)

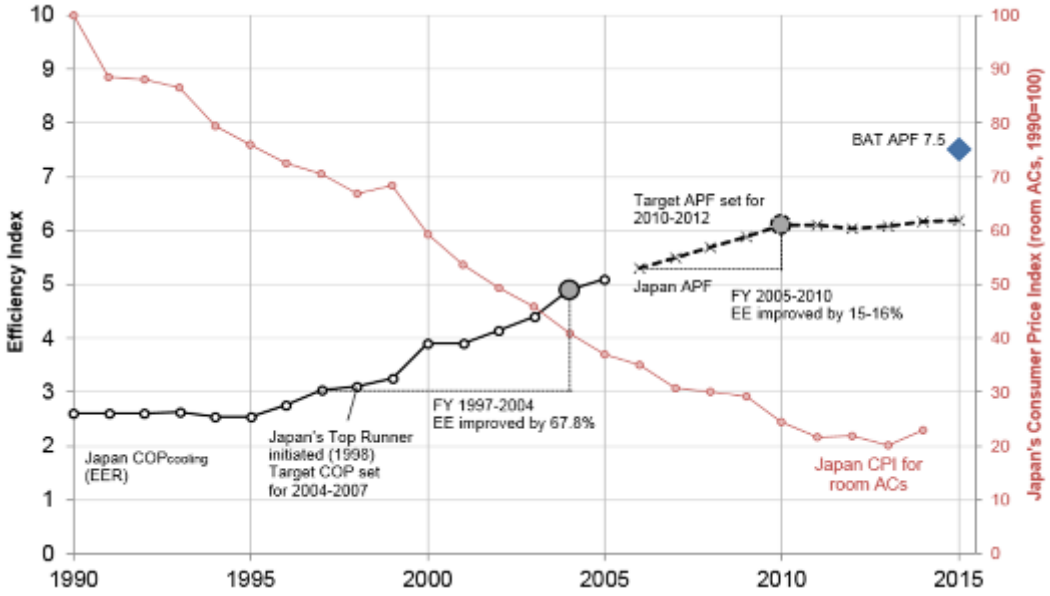
Room AC Efficiency and Policies in India

- Bureau of Energy Efficiency's (BEE) labeling program has a 5-star rating system
  - For appliances with mandatory labeling, 1-star serves as the Minimum Energy Performance Standard (MEPS)
  - Currently, labels are mandatory for fixed speed room ACs and voluntary for variable speed room ACs
  - Starting 2018, fixed and variable speed categories would be merged with mandatory labels for all room ACs



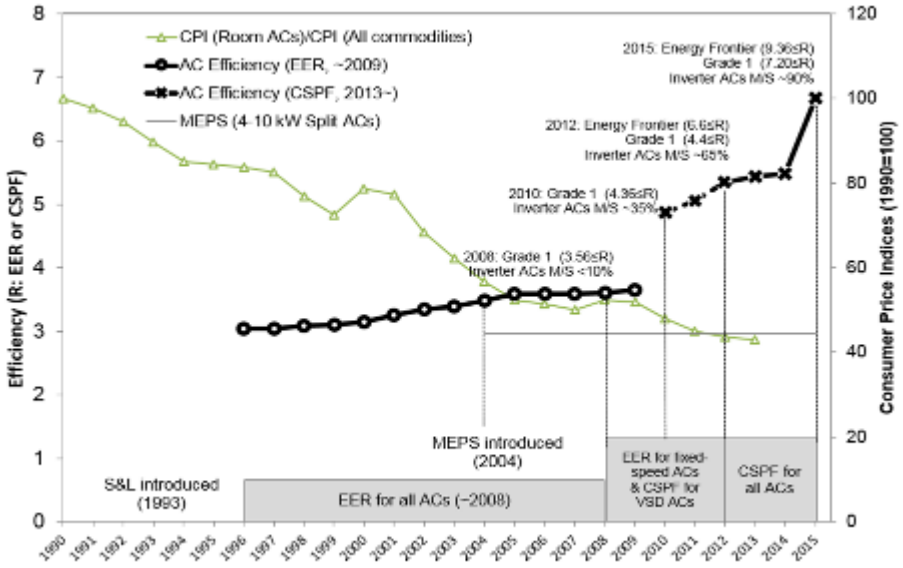
- Room AC Efficiency has been improving while costs continue to decline
  - Room AC star labels have been ratcheted up by one star equivalent every two years
  - Between 2006 and 2016, room AC MEPS has increased by 35% (~3% per year)
  - Market average efficiency, slightly higher than MEPS, has improved similarly
  - In the same period, inflation adjusted room AC prices (Wholesale Price Index) relative to the basket of all commodities, have fallen by over 35%

Accelerated Efficiency Improvement Driven by Policy: Japan's Top Runner Program



- Japan's Top Runner Program (1997) mandated a sales weighted average fleet COP of 5.3 (W/W) for small room ACs and 4.9 (W/W) for larger room ACs by 2004
  - This was ~60% more efficient than the market average efficiency in 1997
  - The target was determined by the COP of the most efficient AC model in the market
- Between 1995 and 2005, room AC efficiency in Japan improved by ~100% (from COP of 2.55 to 5.10 improving at a rate of 7.2% per year)
  - In the same period, inflation adjusted prices declined by over 80%
- Post-2009, consumer financial incentives (Eco-Point System) helped uptake of efficient ACs

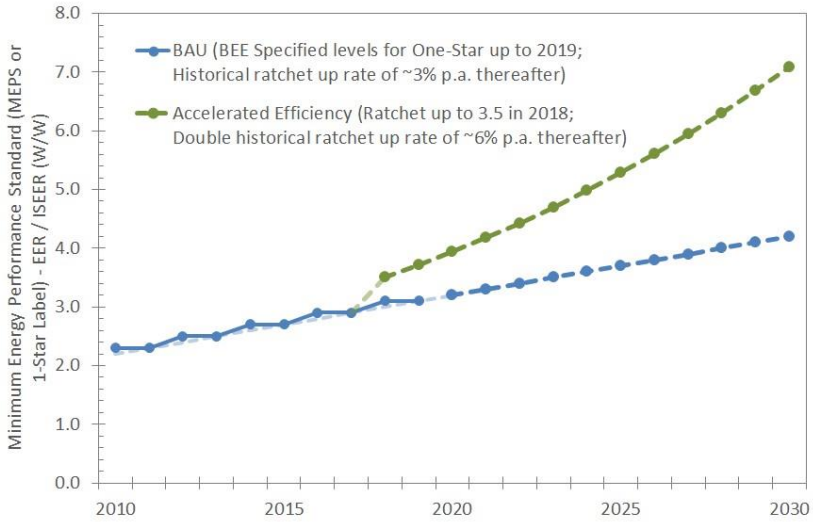
Accelerated Efficiency Improvement Driven by Policy: Korea's Energy Frontier Program



- Energy Frontier Program (2011) sets the energy efficiency criteria for key appliances to be 30-50% more efficient than Grade 1 (most efficient label)
- Between 2008 and 2015, Grade 1 efficiency criteria increased efficiency requirements by over 100% (~12% per year); Energy Frontier is 30-50% above the Grade 1 level
  - Most new models by LG and Samsung meet either the Grade 1 or the Energy Frontier criteria
  - Most efficient room AC model (meets the energy frontier criteria) has CSPF of 9.4
- During this period, inflation-adjusted room AC prices (CPI) continued to decline
- Since 2008, Korea has offered financial incentives for purchase of efficient appliances e.g.
  - Carbon Cashbag program (financial incentives for consumers and advertising etc incentives for manufacturers)
  - Feebates (tax on certain appliances to subsidize purchase of efficient appliances for low-income households)

Technical Feasibility, Impact, and Cost-Benefit of Accelerating room AC Efficiency Improvement

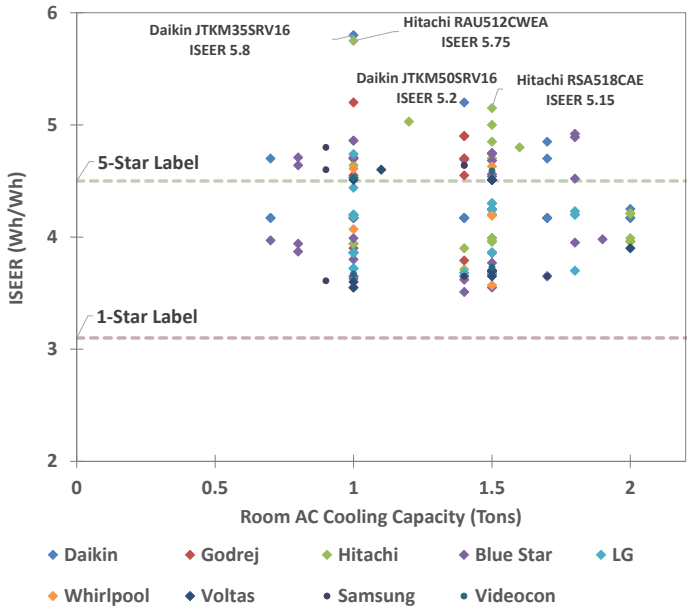
Scenarios for Analysis



- Business as Usual (BAU)
  - Star levels up to 2019 per BEE specified schedule (one-star level of ISEER 3.1) and it is ratcheted up at the historical rate of (3.0% per year) thereafter reaching an ISEER of 4.2 by 2030
  - Equivalent to a market average ISEER of 3.5 in 2018 and 5.0 in 2030

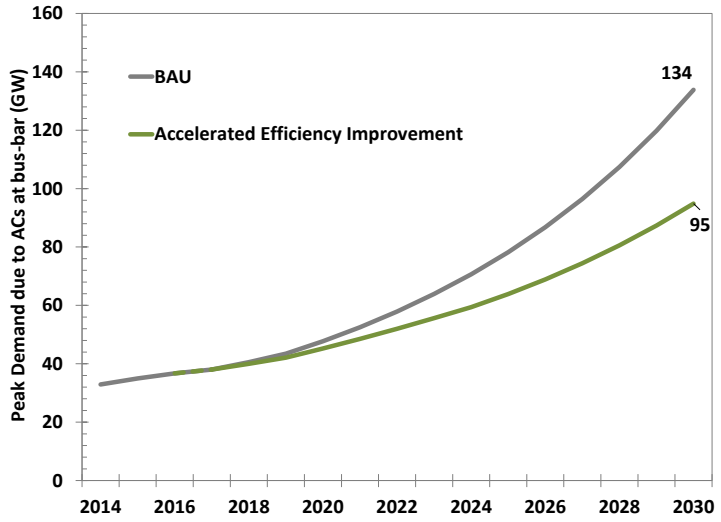
- Accelerated Efficiency Improvement
  - Room AC MEPS is revised to ISEER 3.5 in 2018 (against 3.1 specified by BEE) and it is ratcheted up at double the historical rate (6.0% per year) thereafter reaching an ISEER of 7.1 by 2030
  - Equivalent to market average ISEER of 3.9 in 2018 and 7.9 in 2030
    - Korean CSPF 9.4, equivalent to ISEER 7.9, is one of the most efficient products available globally in 2016
  - By 2022, best available technology available in India (1.5 Ton category) in 2016 becomes the market average (ISEER 5)
  - By 2030, best available technology available globally in 2016 becomes the market average (ISEER 7.9)

Technical Feasibility of the Accelerated Efficiency Improvement Scenario

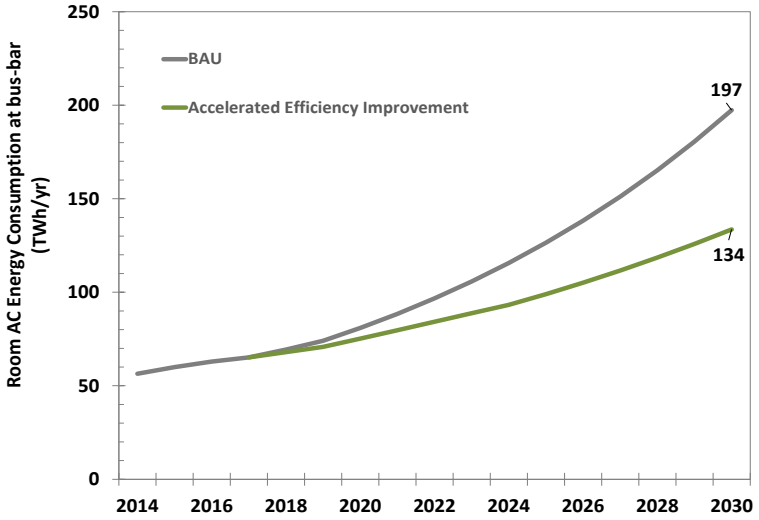


- Figure shows ISEER levels of most of the inverter AC models that are registered with BEE (as of April 2017) arranged by cooling capacity; it also shows the BEE-specified 1-star and 5-star levels up to 2019
  - Most efficient model sold in India has ISEER of 5.8 (1-ton capacity)
- Most brands in India already have room AC models with ISEER >4.5, which is the suggested one-star level by 2022 in the accelerated efficiency improvement scenario
  - Manufacturers appear to possess the technology even today
- Note that the ISEER of 5.8 as well as Korean CSPF of 9.4 (equivalent to ISEER 7.9) has been achieved for capacities lower than 1.5 tons, which are the most commonly used models in India
  - Anecdotal interviews with industry experts indicate that there should not be any technical constraints in achieving similar ISEER in 1.5 ton models as well

Impact of the accelerated improvement in AC efficiency on total energy consumption and national peak load

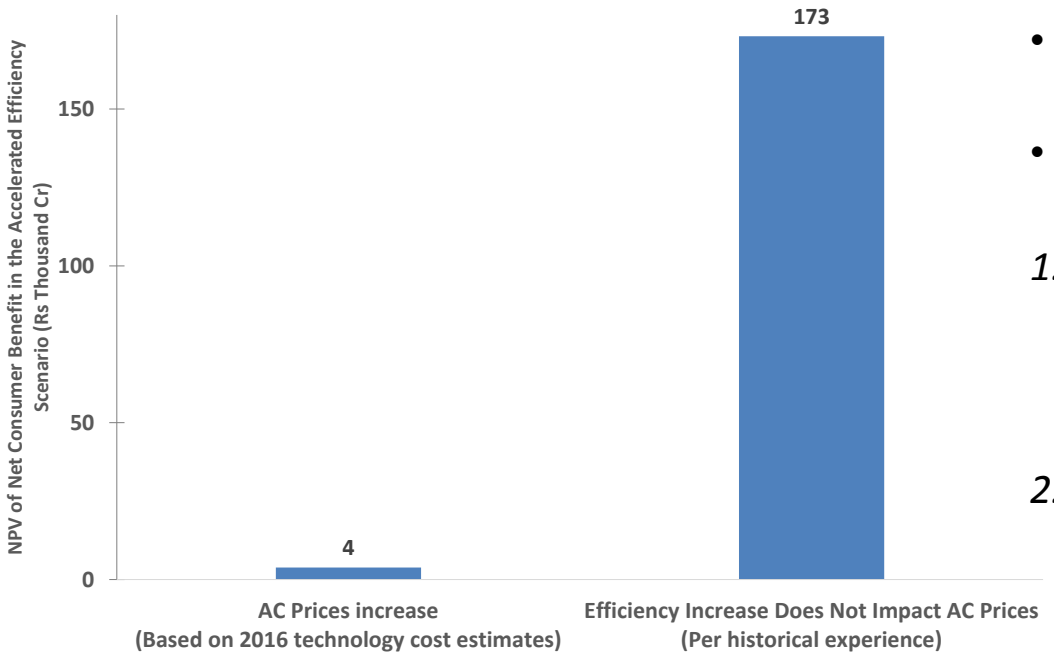


- In the BAU trajectory, by 2030, peak load due to room ACs would be about 134 GW at bus-bar
- **With accelerated efficiency improvement, peak load could be reduced by over 40GW**
  - This is equivalent to avoiding 80 large power plant units of 500MW each



- By 2030, under the accelerated efficiency improvement scenario, room AC consumption could be reduced by nearly 64 TWh/yr at bus-bar without compromising any cooling service
  - This is equivalent to the total energy generation from nearly 40 GW of solar PV capacity

Net Consumer Benefit



- Room AC efficiency improvement creates large consumer benefits.
- We create two scenarios for assessing the benefit:

1. AC prices increase

  - As room ACs get more efficient, their prices increase per the engineering economic assessment in 2016. Pleaser refer to Shah et al (2016) for more details.

2. Efficiency Increase Does not Impact Prices

  - Per historical experience in several countries (including India), efficiency improvement has no impact on AC prices

- Even if the future AC prices increase per the 2016 engineering economic assessment (highly conservative), net consumer benefit is positive i.e. electricity bill reduction due to an efficient AC is higher than its incremental cost
- The NPV of the net consumer benefit between 2018 (first year of the proposed aggressive ratchet) and 2030 would range between Rs. 4,000 Cr ($600 mn) at the minimum (if AC prices increase with efficiency) to Rs. 173,000 Cr ($25 bn) in a more realistic case (if efficiency increase does not impact AC prices per historical experience)
- AC efficiency improvement will also have significant utility benefits due to peak load reduction
- Rebound effect (increase in appliance use due to saving in energy bills) may reduce these benefits – however, that also implies higher cooling service and thus higher consumer welfare

Policies and Programs to Accelerate Room AC Efficiency Improvement

Accelerated Ratcheting Up of BEE Star Rating Levels

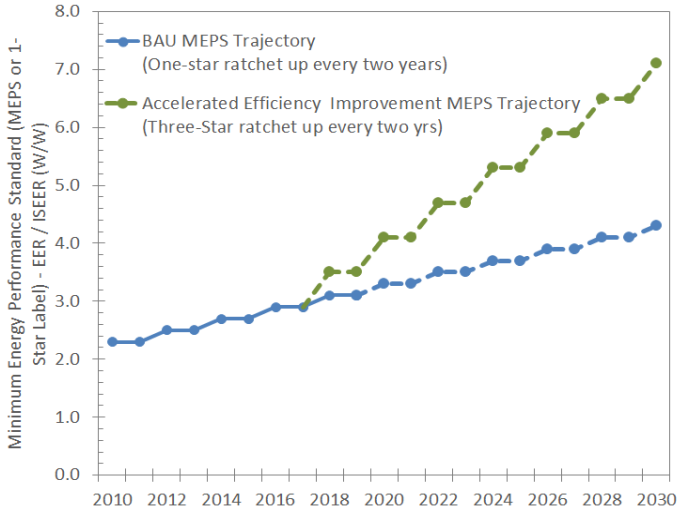
- Experience in India and several other countries have shown that efficiency is significantly driven by MEPS (e.g. 1-star) and related energy efficiency labeling levels.
  - For example, in India, 2 and 3-star labeled ACs dominate the market even with increasing stringency of the star labels

- Accelerating the ratcheting up of star levels is one strategy to accelerate the market average efficiency improvement
  - So far, efficiency for all star levels increase by one star equivalent every two years
  - Accelerating the ratchet does not mean more frequent revisions; can be achieved with more stringent levels for each revision

- Introducing and accelerating star rating for other types of space cooling equipment
  - For example, chillers, Variable Refrigerant Flow (VRF) multi-split ACs, ducted split ACs and rooftop ACs as their penetration increases
  - This will need a number of related interventions such as test procedure development, capacity building of test labs, development of appropriate efficiency metrics, and integration with building codes and standards

Provide Policy Direction with Medium to Long Term Targets for Star Levels

- Similar to Japan's Top Runner Program, long term targets provide a broader policy direction
  - E.g. today's best available technology in India (1.5 Ton size) becomes the market average efficiency level by 2022 (ISEER 5) or today's best available technology globally becomes the market average by 2030 (ISEER 7.9)
- Once long term target is set, BEE can ratchet up the MEPS in interim years
  - Widen the spread of the star labels to incentivize more efficient products to be sold on the market
  - Ratchet up the star levels every two years by two stars instead of one e.g. within 3 revisions (up to 2022), the current five-star label becomes the MEPS (one-star label)



- Chart shows one such potential schedule of ratchets to achieve the accelerated efficiency improvement trajectory for achieving two long term goals –
  - Today's five star becomes the one-star label in 2022 (ISEER 4.5), and
  - Today's globally available best commercial technology becomes the market average in 2030 (implying market average of ISEER 7.9 and one-star label of 7.1)

Bulk Procurement & Incentives to Support Accelerated Ratcheting Up of S&L Levels

- Bulk procurement can reduce the cost of efficient air conditioners and incentives can address the first cost barrier
  - India has recently announced its intent to launch an efficient room AC program similar to the successfully implemented UJALA LED program

- Bulk procurement and incentive programs will be crucial for supporting the accelerated ratcheting up of star levels
  - For example, increasing the market share of five-star ACs will allow an easier transition to the same efficiency level being characterized as a two or three star level a few years later
  - Such programs can bring super-efficient products (significantly beyond five star) to the market and will be crucial in pulling up the top of the market

- Design of such programs is crucial to ensuring the overall benefits are maximized and the “freerider” effect is avoided
  - i.e. consumers using incentives when they would have purchased the appliance without it or with a lower incentive level

Conclusion

- We assess technical feasibility, cost-benefit, and policy enhancements for accelerating the room AC efficiency improvement in India
- Most efficient room AC on the Indian market is almost twice as efficient as the market average room AC
  - Japan and Korea have doubled room AC efficiency in 7-10 yrs while inflation-adjusted room AC prices declined
  - Hence, we do not think that technology will be a constraint in accelerating the room AC efficiency
- If starting 2018, market average AC efficiency improves at 6%/yr instead of historical average of 3%/yr:
  - ~40GW of peak load could be avoided by 2030 (equivalent to ~80 power plants of 500MW each), and
  - ~64TWh/yr of energy could be saved by 2030 (equivalent to current electricity consumption of Gujarat state)
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Appendix

Key Assumptions and Projections

Key assumptions and parameters:

Parameter	Assumption
AC size	1.5 Tons (5.25 kW)
Hours of use	1200 hours/yr
Annual energy consumption of AC	(AC Size / ISEER value) * Hours of use
Electricity price	6 Rs/kWh in 2016 increasing at 6% p.a.
Discount rate	8%
Life of the AC	7 years
T&D loss	15%
Peak coincidence factor	0.7

Summary of sales, stock, and demand projections:

	2015	2020	2025	2030
Room AC sales (millions/yr)	4	8	14	24
Room AC live stock (millions)	24	38	69	124
Total Room AC Consumption at bus-bar (BAU Scenario) TWh/yr	60	81	126	197
Total room AC Peak Load at bus-bar (BAU scenario) GW	35	48	78	134

Estimates of AC Retail Prices for Evaluating Consumer Benefits

Market Average ISEER (Wh/Wh)	Equivalent Market Average EER (W/W)	Estimated Retail Price Rs. (based on 2016 technology cost assessments)
3.7	3.5	39588
3.9	3.7	40188
4.1	3.8	44436
4.4	4.0	48300
4.6	4.2	48828
4.9	4.4	53076
5.2	4.6	55404
5.5	4.8	64212
5.8	4.9	65940
6.1	5.1	72608
6.5	5.3	77370
6.9	5.4	82131
7.3	5.6	86892

Notes:

1. The price estimates are based on the engineering economic assessment of the manufacturing costs of efficiency improvement from Shah et al (2016).
2. A particular value of ISEER could be achieved by multiple combinations of efficient components such as efficient compressors, better UA of heat exchangers, variable speed drives, etc. Therefore, depending on the components chosen, same ISEER level may have multiple EERs or vice versa. For details, refer to Shah et al (2016).

Sensitivity Analysis

In order to test the sensitivity of our results to the key assumptions / parameters, we re-estimate the benefits in a range of +/- 25% of the original values of these parameters

	Base Case	Sensitivity on Peak Coincidence Factor		Sensitivity on hours of use		Sensitivity on AC Sales Growth	
Room AC Sales Growth % p.a.	*12.5%*	12.5%		12.5%		9.4%	15.6%
Hours of use/year	*1,200*	1,200		900	1,500	1,200	
Peak Coincidence Factor	*0.7*	0.525	0.875	0.7		0.7	
Total Energy Saving at bus-bar in 2030 (TWh/yr)	*64*	64	64	48	80	48	80
Total Peak Load Reduction at bus-bar in 2030 (GW)	*39*	29	49	39	39	29	49
NPV of Net Consumer Benefit (If AC Prices Increase) - Rs Thousand Cr	*4*	4	4	-39	47	3	5
NPV of Net Consumer Benefit (If Efficiency Improvement has no impact on AC prices) Rs Thousand Cr	*173*	173	173	130	217	130	217

Other key assumptions: Electricity price = Rs 6/kWh increasing at 6% per year; Discount Rate = 8%; T&D losses = 15%